Astron. Nachr. / AN **xxx**, No. xx, 1 – 8 (2007) / **DOI *please set DOI!***

Astrophysical supplements to the ASCC-2.5. Ia. Radial velocities of ∼55000 stars and mean radial velocities of 516 Galactic open clusters and associations

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Received 25 Jan 2007, accepted 23 Apr 2007
Published online ...

Key words radial velocity – open clusters

We present the 2nd version of the Catalogue of Radial Velocities with Astrometric Data (CRVAD-2). This is the result of the cross-identification of stars from the All-Sky Compiled Catalogue of 2.5 Million Stars (ASCC-2.5) with the General Catalogue of Radial Velocities and with other recently published radial velocity lists and catalogues. The CRVAD-2 includes accurate J2000 equatorial coordinates, proper motions and trigonometric parallaxes in the Hipparcos system, B, V photometry in the Johnson system, spectral types, radial velocities (RVs), multiplicity and variability flags for 54907 ASCC-2.5 stars. We have used the CRVAD-2 for a new determination of mean RVs of 363 open clusters and stellar associations considering their established members from proper motions and photometry in the ASCC-2.5. For 330 clusters and associations we compiled previously published mean RVs from the literature, critically reviewed and partly revised them. The resulting Catalogue of Radial Velocities of Open Clusters and Associations (CRVOCA) contains about 460 open clusters and about 60 stellar associations in the Solar neighbourhood. These numbers still represent less than 30% of the total number of about 1820 objects currently known in the Galaxy. The mean RVs of young clusters are generally better known than those of older ones.

1 Introduction

In this paper we present the 2nd version of the Catalogue of Radial Velocities (RVs) of Galactic stars with high precision Astrometric Data (CRVAD-2). As a first application of this enlarged data set we have compiled a new Catalogue of Radial Velocities of Open Clusters and Associations (CRVOCA) currently known in the Galaxy.

The first version of the CRVAD (Kharchenko, Piskunov & Scholz 2004a, hereafter Paper I) was the result of the cross-identification of the All-Sky Compiled Catalogue of 2.5 Million Stars (ASCC-2.5; Kharchenko 2001) with the General Catalogue of Radial Velocities (GCRV; Barbier-Brossat & Figon 2000). The CRVAD included about 33 500 stars. Since some new big RV catalogues have been published recently, including original observational data (Nordström et al. 2004; Famaey et al. 2005) as well as new RV compilations (Goncharov 2006), we have built an extended RV list of about 55 000 stars which now forms the 2nd CRVAD version.

A new ambitious RV survey of the southern sky, the RAdial Velocity Experiment (RAVE), has been initiated a few years ago as a wide international collaboration (Steinmetz 2003). The first RAVE data release containing RVs for about 25 000 stars, has already been published (Steinmetz et al. 2006), the second data release is expected in early 2007 and will probably contain about twice as many stars. We have not yet included RAVE measurements in the construction of the CRVAD-2 so that the latter can be considered as the pre-RAVE status on stellar RVs in the Galaxy.

More than 200 000 RVs of generally fainter stars are included in the latest Sloan Digital Sky Survey (SDSS) data release (DR5; Adelman-McCarthy et al. 2007). This number will be more than doubled by the Sloan Extension for Galactic Understanding and Exploration (SEGUE) project targetting stars fainter than 14th magnitude in about 200 sky fields covering the sky visible from the northern hemisphere (see e.g. Re Fiorentin et al. 2007). The SDSS and SEGUE RVs are of lower accuracy (∼10-20 km/s; Ivezic 2006) than those of the RAVE survey (typically ∼2 km/s; Steinmetz et al. 2006)

The ASCC-2.5 is based on stellar data from the catalogues of the Hipparcos-Tycho family, including the Tycho-2 catalogue, and provides the most complete all-sky catalogue of stars having uniform high precision astrometric and photometric data down to $V \approx 14$ with a completeness limit at $V \approx 11.5$. The ASCC-2.5 has been the main tool for our studies of open clusters. Based on ASCC-2.5 data we identified 513 known open clusters and 7 known com-

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pact stellar associations (Kharchenko et al. 2005a) and detected 130 new open clusters (Kharchenko et al. 2005b). A uniform combined spatial-kinematical-photometric cluster membership analysis (Kharchenko et al. 2004b) was implemented for all 650 objects and new uniform scales of cluster properties (structure, photometry, evolution, and kinematics) were established. All these properties were determined from cluster members in the ASCC-2.5, and mean cluster radial velocities $\overline{\mathrm{RV}}$s were obtained from cluster members in the CRVAD. In this paper we have used the CRVAD-2 for determining and/or revising the $\overline{\mathrm{RV}}$s for all open clusters and associations with available measurements.

Distinguishing (young) "open clusters" and "stellar associations" (or "OB associations") is not a trivial task (Brown 2001), and one can find different classifications of the same object in the literature. For instance, the well known open cluster Melotte 20 (α Per) is also being called the Per OB3 association (Mel'nik & Efremov 1995; de Zeeuw et al. 1999), whereas the Cyg OB2 association is also being studied as a (super-star) cluster (Hanson 2003) or even as a young globular cluster (Knödlseder 2000) based on its mass estimates. Our list of 650 objects identified in ASCC-2.5 data therefore includes several cluster-like associations (e.g. Vel OB2, Sco OB4). On the other hand, some objects used to be called open clusters and we continue to do so, although they could be considered as associations according to their ages and stellar content. Several open clusters represent association cores (e.g. ASCC 16; Briceño et al. 2005; Kharchenko et al. 2005b). In order to get a complete picture on the current status of open cluster radial velocities, we decided to include not only Galactic open clusters but also the known stellar associations in the Galaxy in the construction of the CRVOCA.

For the last decades stars in clusters have been much more attractive targets for RV measurements than field stars. This is obvious from looking at the sky distribution of bright stars with available RV measurements (see e.g. Fig. 5 in Paper I). The increased number of stars in the CRVAD-2 still represents only about 2% of the ASCC-2.5 stars over the whole sky. However, the RV stars are concentrated in sky areas with open clusters, where about 5% of the ASCC-2.5 stars have RV measurements. For fainter stars the non-uniform distribution of RV measurements over the sky is even more pronounced since many special observing programs are being carried out for fainter open cluster members in order to obtain cluster $\overline{\mathrm{RV}}$s.

Nevertheless, our knowledge on open cluster $\overline{\mathrm{RV}}$s is much poorer than on their proper motions. According to Dias et al. (2002) (we refer here to the updated online database, v. 2.7, 2006/10/27 at http://www.astro.iag.usp.br/~wilton/), $\overline{\mathrm{RV}}$s have been published for only 361 out of about 1760 known clusters, All these data are very inhomogeneous: sometimes the $\overline{\mathrm{RV}}$ of a cluster is taken from measurements of only one star, sometimes the rms errors reach 30 km/s, and some authors did not give any information on the accuracy at all.

Table 1 Statistics of the CRVAD-2 according to the source catalogues

Source catalogue	Index	Number of ASCC-2.5 stars
Famaey et al. (2005)	1	3488
Goncharov (2006)	2	5756
Nordström et al. (2004)	3	15245
CRVAD (Barbier-Brossat & Figon 2000)	4	27636
Average CRVAD & Famaey et al. (2005)	5	2782

In building the CRVOCA we also included a critical review of all available data on $\overline{\mathrm{RV}}$s of open clusters and associations in the literature. In cases where several literature values were available, we gave preference to the most reliable data. In that respect, we reviewed the number of cluster members used for the determination of the $\overline{\mathrm{RV}}$s, the applied method of membership determination, and the year of publication.

In Sec. 2 we describe the construction of the CRVAD-2. Sec. 3 includes statistics on the objects in the CRVAD-2 and a summary of its content. In Sec. 4 we give the details on the construction of the CRVOCA and summarise its content, and in Sec. 5 we consider the new census of $\overline{\mathrm{RV}}$s of open clusters and associations and compare our own determinations of $\overline{\mathrm{RV}}$s with data from the literature.

2 Construction of the CRVAD-2

The CRVAD-2 is the result of updating and expanding the list of stars with known RVs and high precision astrometric and photometric data. These data were taken from the ASCC-2.5 catalogue (Kharchenko 2001), which is mainly based on the Hipparcos and Tycho catalogues, including the Hipparcos Multiple System Annex. The ASCC-2.5 contains equatorial coordinates and proper motions in the Hipparcos system, as well as B, V stellar magnitudes in the Johnson system. Additionally, trigonometric parallaxes, spectral types, multiplicity and variability flags (if avaliable in Hipparcos and Tycho-2), as well as HD and BD designations are given.

The RVs in the first version of the CRVAD (Paper I) were taken from the GCRV, which supplemented the Wilson-Evans-Batten catalogue (Dufolt, Figon & Meyssonier 1995) with observations published until December 1999. In the cross-identification process of the ASCC-2.5 with the GCRV all the relevant information (including identifiers, coordinates) was used. A detailed description of the cross-identification was given in Kharchenko et al (2004b). The first version of the CRVAD contained 34 553 stars from the ASCC-2.5 identified with 33 509 stars from the GCRV.

Three recently published RV catalogues, which we used for expanding our RV data base into the CRVAD-2, are briefly described in the following:

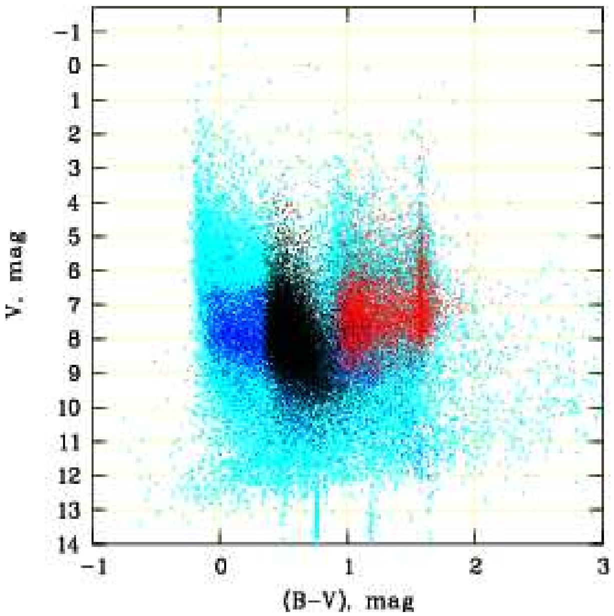

Fig. 1 Colour-magnitude diagram of the CRVAD-2 stars (cyan points). Black, red and blue points correspond to stars from Nordström et al. (2004), Famaey et al. (2005) and Goncharov (2006), respectively.

Nordström et al. (2004) published their results of the Geneva-Copenhagen survey of the Solar neighbourhood for nearby F and G dwarfs. Their RV catalogue includes 14 139 stars, the majority of which (about 13 500 stars) were measured by Nordström et al. (2004) with the photoelectric cross-correlation spectrometers CORAVEL. The RVs for 675 of their stars were taken from the GCRV, and therefore we did not consider them as new data. On the other hand, about 2400 of the stars with newly determined RVs were already included in the GCRV of Barbier-Brossat & Figon (2000), where some of these stars were listed with preliminary observational results. In the construction of the CRVAD-2 we replaced the data of these stars with the final results from Nordström et al. (2004). In the cross-identification of the Nordström et al. (2004) catalogue with the ASCC-2.5 we again used all available data, including the coordinates and component identifiers of multiple stars.

Famaey et al. (2005) published their results of the local kinematics of 6 691 K and M giants from CORAVEL RVs and Hipparcos/Tycho-2 proper motion data. After excluding the binaries for which no center-of-mass RV could be measured, their catalogue includes 6 029 Hipparcos stars. For about 2 800 of these stars, RVs were already listed in the GCRV, and we computed the weighted means of the two RV values and included them in the CRVAD-2. The cross-identification with the ASCC-2.5 was carried out by Hipparcos numbers.

Recently Goncharov (2006) presented the Pulkovo Compilation of Radial Velocities (PCRV), where he included the RVs of about 35 500 Hipparcos stars taken from all the above mentioned big catalogues as well as from practically all smaller lists with heliocentric RVs published until 2004. Only the data of the latter lists were taken for completing the CRVAD-2 list of stars. Here we used again the Hipparcos numbers for the cross-identification. Note that part of the PCRV stars have also been published and analysed as the Orion Spiral Arm CAtalogue (OSACA) by Bobylev, Goncharov & Bajkova (2006).

3 Statistics and content of the CRVAD-2

Altogether 54 907 stars from the ASCC-2.5 were identified with 51 762 stars from the RV source catalogues, 3 085 stars have secondary components and 30 stars have 3rd components in multiple systems. In cases where an ASCC-2.5 multiple star was not resolved in the RV source catalogue, the same RV value was asigned to all components. These objects were flagged in the CRVAD-2. Table 1 gives the numbers of stars in the CRVAD-2 according to the source catalogues but including the components of multiple systems. The index corresponds to the designation of a source catalogue in the CRVAD-2.

The apparent colour-magnitude diagram of the CRVAD-2 objects is shown in Fig. 1. As one can see, the ≈20 000 new RV stars in the CRVAD-2 occupy an intermediate magnitude interval and do not extend the CRVAD to a fainter magnitude limit.

The CRVAD-2 contains accurate equatorial coordinates J2000, proper motions and trigonometric parallaxes in the Hipparcos system, BV magnitudes in the Johnson system, variability and multiplicity flags, and component identifiers from the ASCC-2.5, as well as radial velocities from the source catalogues. Spectral types are given from two different data sets. One spectral type information is taken either from the ASCC-2.5 (mostly from Hipparcos and the PPM catalogue) or from the GCRV, where our preference was given to the most detailed spectral type. In a second column, we list the information from the Tycho-2 Spectral Type Catalog of Wright et al. (2003) providing the most complete list of stars with very detailed spectral classification. As in the CRVAD, the RVs are not always listed with individual measuring errors ϵ_{RV}. Only 71% of the CRVAD-2 stars have ϵ_{RV} values copied from the source catalogues. Further 21.5% have RV quality indices (A, B, C, D, E, or I) taken from Dufolt et al (1995), which correspond to standard errors of 0.74, 1.78, 3.70, 7.40, 10.0 km/s or to the case of insufficient data, respectively. For the remaining 7.5% of the CRVAD-2 stars ϵ_{RV} were not available.

4 Radial velocities of open clusters and stellar associations

4.1 Object list

The most complete list of open clusters described by Dias et al. (2002) contains 1759 objects after the last update (v. 2.7, 2006/10/27). This list does not contain all 650 objects for

Table 2 Contents of the CRVAD-2

	Label	Units	Explanations
1	RAhour	h	Right Ascension J2000.0, epoch 1991.25
2	DEdeg	deg	Declination J2000.0, epoch 1991.25
3	e_{RA}	mas	Standard error of Right Ascension
4	e_{DE}	mas	Standard error of Declination
5	Plx	mas	Trigonometric parallax
6	e_{Plx}	mas	Standard error of parallax
7	pmRA	mas/yr	Proper Motion in RA·cos(DE)
8	pmDE	mas/yr	Proper Motion in DE
9	e_{pmRA}	mas/yr	Standard error of pmRA
10	e_{pmDE}	mas/yr	Standard error of pmDE
11	B	mag	B magnitude in Johnson system
12	V	mag	V magnitude in Johnson system
13	e_B	mag	Standard error of B magnitude
14	e_V	mag	Standard error of V magnitude
15	Scat	mag	Scatter in magnitude from Hipparcos or Tycho-1
16	v1	—	Known variability from Hipparcos
17	v2	—	Variability from Tycho-1
18	v3	—	Variability type from Hipparcos
19	v4	—	Variability from CMC11
20	d12	—	CCDM component identifier
21	d3	—	Component identifier from Hipparcos
22	d4	—	Duplicity from Tycho-1
23	d5	—	Double/Multiple Systems flag from Hipparcos
24	d6	—	Duplicity flag from PPM
25	Sp_1	—	Spectral type from ASCC-2.5 or GCRV
26	Sp_2	—	Spectral type from Wright et al. (2003)
27	HIP	—	Hipparcos number
28	HD	—	HD number
29	ASCC	—	ASCC-2.5 number
30	I_{sc}	—	Index of source catalogue
31	comp	—	Components of multiple star or duplicity flag
32	RV	km/s	Radial Velocity
33	e_{RV}	km/s	Mean standard error of the RV
34	q_{RV}	—	Quality index of the RV (A,B,C,D,E,I)
35	N_{RV}	—	Number of observations
36	N_{mult}	—	Number of matches in the source catalogue for given entry

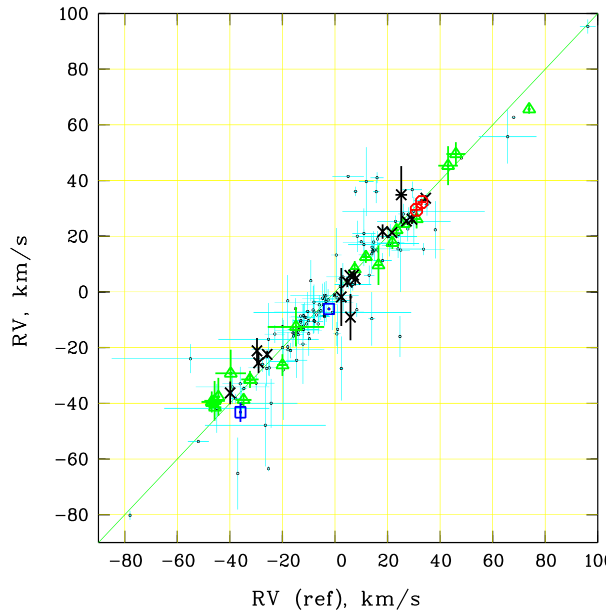

Fig. 2 Comparison of cluster $\overline{\mathrm{RV}}$s derived in this study with published data (RV (ref)). Error bars indicate r.m.s. errors of the $\overline{\mathrm{RV}}$s (or of an individual RV measurement, if only one cluster member star was available) Different symbols represent the comparison with the following sources: black crosses - Mermilliod et al. (1998), Mermilliod & Mayor (1989), Mermilliod & Mayor (1990), Mermilliod & Mayor (1999), Mermilliod, Mayor & Burki (1987); red circles - Friel et al. (2002), Thorgersen, Friel & Fallon (1993); blue squares - Turner (1992), Turner, Forbes & Pedreros (1992); green triangles - Liu, Janes & Bania (1991).

which Kharchenko et al. (2005a, 2005b) determined a homogeneous set of parameters, since the latter included seven cluster-like associations (Vel OB2, Nor OB5, Sco OB4, Sco OB5, Sgr OB7, Cyg OB2, Cep OB3). As there is no sharp distinction between open clusters and associations in the literature, we decided to add all stellar associations from Mel'nik (2007) so that our extended list contained 1821 objects. Note that among the about 80 associations listed by Mel'nik (2007), there are many objects which used to be named open clusters, and treated as such in Kharchenko et al. (2005a) and Dias et al. (2002).

4.2 $\overline{\mathrm{RV}}$ determination on the basis of the CRVAD-2

Based on the previously available RVs in the CRVAD, we had obtained $\overline{\mathrm{RV}}$s of open clusters using their determined members from the Catalogue of Stars in Open Cluster Areas (CSOCA) and its first extension (Kharchenko at al. 2004b, 2005b). In this previous solution (for a summary, see Scholz et al. 2005), we were able to get $\overline{\mathrm{RV}}$s for 322 out of 650 clusters (here and in the following we call all 650 objects clusters, but keep in mind that 7 of them are cluster-like associations) identified in the ASCC-2.5. The data were presented together with other cluster parameters in the Catalogue of Open Cluster Data (COCD) and its first extension (Kharchenko at al. 2005a, 2005b).

Now, with the newly collected data in the CRVAD-2, we have updated the RV solutions for a larger number of open clusters. A new sample of open cluster members with RV measurements was obtained from a cross-identification of the CRVAD-2 with cluster members from the CSOCA and its first extension. The method for determining combined spatial-kinematical-photometric membership probabilities P_c has been described in detail by Kharchenko et al. (2004b).

All possible members ($P_c > 1\%$) with RV measurements were involved in the determination of $\overline{\mathrm{RV}}$s. In all 650 clusters investigated there are about 38 500 possible cluster members in total, from which only 4.8% have RV measurements. For 32 clusters, lacking such possible members with

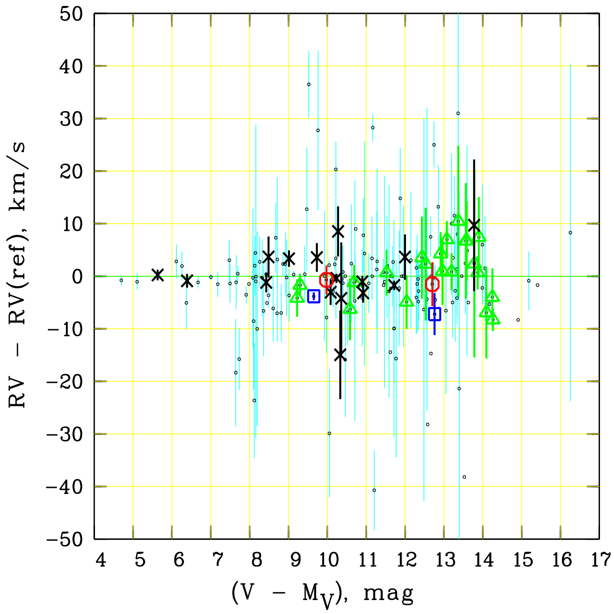

Fig. 3 Differences between published $\overline{\mathrm{RV}}$s and $\overline{\mathrm{RV}}$s from this study versus cluster distance. The designations are the same as in Fig. 2.

available RVs, we used one bright RV star per cluster which could be considered as a member based on its proper motions only. This assumed cluster member lies on the upper main sequence or giant branch and probably failed our photometric membership criterion due to intrinsic stellar variability and/or a non-uniform extinction in the cluster area. In all these cases we re-analysed the location of the star in the proper motion diagram and in the colour-magnitude diagram, and the corresponding clusters are marked in the CRVOCA with $N_{\mathrm{RV}} = -1$.

For 162 clusters there were more than two possible member stars with measured RVs available (the average number of RV stars in these clusters was 9 with a maximum of 106). For each of these clusters we checked the RVs for consistency and excluded stars with RVs deviating from the average by more than 3 standard deviations from our final solution. The average of the 162 standard errors of the mean cluster radial velocities ($\overline{\mathrm{RV}}$s), determined from our selected members and their RVs in the CRVAD-2, is 4.5 km/s. For 60 clusters with two members and for 124 clusters with only one member and available error of the individual stellar RV (formally considered as the error of the cluster $\overline{\mathrm{RV}}$) the average errors are 4.9 and 4.6 km/s, respectively. 17 clusters with $\overline{\mathrm{RV}}$s obtained from the CRVAD-2 have no error estimate.

Altogether, we used 1749 stars from the CRVAD-2 for determining $\overline{\mathrm{RV}}$s of 363 out of 650 clusters. In case of 246 clusters our previously determined $\overline{\mathrm{RV}}$s were confirmed, for 76 clusters we got improved values, and for 41 clusters we computed their $\overline{\mathrm{RV}}$s for the first time based on our membership analysis and available RVs in the CRVAD-2.

4.3 Literature data

Several major catalogues of $\overline{\mathrm{RV}}$s of open clusters and stellar associations have been published so far:

Hron's (1987) $\overline{\mathrm{RV}}$s were calculated using some weighting system for 105 young clusters with stars of earliest spectral types (up to B3). Rastorguev et al. (1999) published $\overline{\mathrm{RV}}$s of 117 open clusters younger than 100 million years, where the data for 40 clusters were taken from Hron (1987). For the remaining 77 clusters they obtained $\overline{\mathrm{RV}}$s from the WEBDA database (http://www.univie.ac.at/webda/), or from original observations by Glushkova & Rastorguev (1991) with a correlation spectrometer. Applying a cluster analysis technique to Galactic OB-stars Mel'nik & Efremov (1995) identified 88 compact groups (association cores) and determined $\overline{\mathrm{RV}}$s for about half of them. A more complete list of associations with respect to $\overline{\mathrm{RV}}$ data was recommended to us by Mel'nik (2007). This list of 81 associations (73 of which have $\overline{\mathrm{RV}}$s) is based on the partition of OB-stars into associations suggested by Blaha & Humphreys (1989). It has been used by Mel'nik, Dambis & Rastorguev (2001) in a kinematical analysis of OB associations. We prefered to use these data, available at http://lnfm1.sai.msu.ru/˜anna/page3.html, instead of those from Mel'nik & Efremov (1995).

The catalogue of Lyngå (1987), not restricted to certain age classes, contains $\overline{\mathrm{RV}}$s for 108 clusters (out of 1150 listed), for which weighted mean values for member star velocities had been published until 1980. The current Dias et al. (2002) collection (v. 2.7, 2006/10/27) of 1759 open clusters includes 361 $\overline{\mathrm{RV}}$s. 121 of the latter were taken from our previous determinations based on the CRVAD.

Besides of the above mentioned catalogues there are several big projects which have contributed substantial numbers of open cluster $\overline{\mathrm{RV}}$s based on observations of cluster members selected by different methods:

One of the most productive projects by Mermilliod and co-workers deals with observations of red giants and eclipsing binaries in open clusters. In a large number of papers by Clariá & Mermilliod (1992), Clariá, Mermilliod & Piatti (1999), Clariá et al. (1994), Clariá et al. (2006), Clariá et al. (2003), Eigenbrod et al (2004), Huestamendia, del Rio & Mermilliod (1990) Mermilliod, Andersen &Mayor (1997), Mermilliod et al. (1997), Mermilliod et al. (1995), Mermilliod et al. (2001), Mermilliod et al. (1996), Mermilliod et al. (2003), Mermilliod et al. (1998), Mermilliod & Mayor (1989), Mermilliod & Mayor (1990), Mermilliod & Mayor (1999), Mermilliod, Mayor & Burki (1987) the $\overline{\mathrm{RV}}$s of 38 open clusters were determined. In addition, Raboud & Mermilliod (1998) and Robichon et al. (1999) determined $\overline{\mathrm{RV}}$s of 14 very nearby clusters based on thoroughly selected cluster members.

An other big project carried out by Friel (1989), Friel & Janes (1993), Friel et al. (2002), Friel, Liu & Janes (1989), Thorgersen, Friel & Fallon (1993) provided physical parameters, including $\overline{\mathrm{RV}}$s, of 28 old open clusters. Liu, Janes &

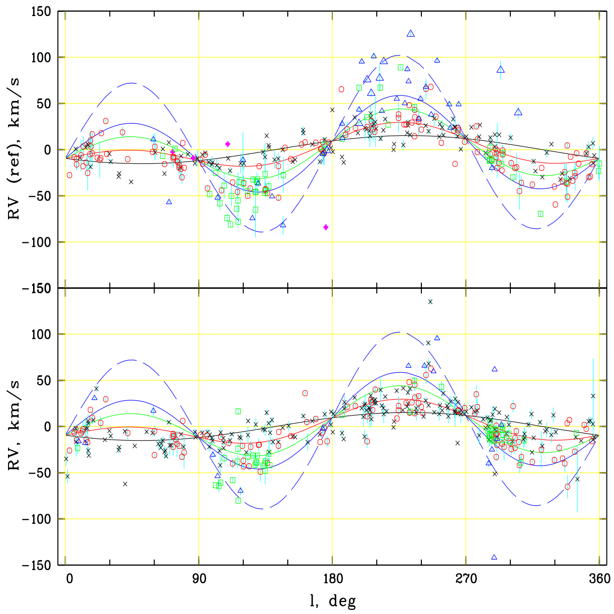

Fig. 4 Cluster $\overline{\mathrm{RV}}$s versus galactic longitude: determined with CRVAD-2 (lower panel) and literature data (upper panel). The curves show the combined effect of Solar motion and differential Galactic rotation on the RVs with $d =$ 0, 1, 2, 3 and 6 kpc from the Sun (black, red, green, blue, blue dashed lines, respectively). Black crosses, red circles, green squares, blue triangles and large blue triangles correspond to the clusters with $d =$ 0...1, 1...2, 2...3, 3...6, and >6 kpc, respectively. Bold magenta pluses mark clusters with unknown d.

Bania (1991) measured $\overline{\mathrm{RV}}$s of 22 younger clusters. High-quality membership selections of open clusters and accurate $\overline{\mathrm{RV}}$s were also presented by Turner (1992), Turner, Forbes & Pedreros (1992); Turner (1993), Turner, Mandushev & Forbes (1994), Turner, Pedreros & Walker (1998).

All $\overline{\mathrm{RV}}$s, available in the above mentioned three catalogues, in the WEBDA database and/or from the many publications of original observational results on stellar RVs in open clusters and associations, were critically reviewed and added to our extended database of 1821 clusters and associations. In the review of the literature RV data we tried to be as complete as possible and to collect the most complete and homogeneous information concerning the errors of $\overline{\mathrm{RV}}$s (some authors, e.g. Friel and co-authors, list standard deviations instead of mean errors). The most reliable data were selected according to more recent publications, to the largest number of cluster members, and to the highest quality of the membership determination procedure. In total, we found $\overline{\mathrm{RV}}$s for 330 clusters and associations from 67 references in the literature.

215 out of the 330 clusters have published $\overline{\mathrm{RV}}$s based on at least two (and up to 81) member stars. Their mean $\overline{\mathrm{RV}}$ error is 4.1 km/s. For 25 clusters with only one member and for 66 clusters with an unknown number of members the mean $\overline{\mathrm{RV}}$ errors from the literature are 2.6 and 6.2 km/s, respectively. 24 clusters have published $\overline{\mathrm{RV}}$s (based on one member or on an unknown number of members) without specified errors. The latter are taken mainly from Lyngå (1987), Mel'nik (2007), and Dias et al. (2002).

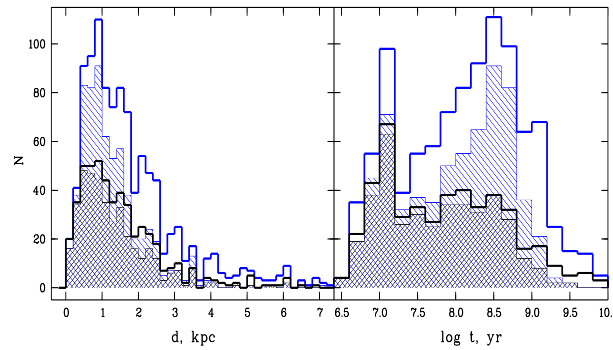

Fig. 5 Distributions of the open clusters with known $\overline{\mathrm{RV}}$s and basic parameters with distance from the Sun (left panel) and with age (right panel). Blue thick lines correspond to the objects with known distances from the Sun (1047 objects) and known ages (997 objects), respectively. Blue thin lines and hatched histograms show the sub-sample of 650 objects from Kharchenko et al. (2005a, 2005b). Black thick lines correspond to the objects with known $\overline{\mathrm{RV}}$s and distances (512 objects), and with $\overline{\mathrm{RV}}$s and ages (465 objects), respectively. Black thin lines and cross-hatched histograms represent 395 clusters from Kharchenko et al. (2005a, 2005b) with known $\overline{\mathrm{RV}}$s.

Table 3 Contents of the CRVOCA

	Label	Units	Explanations
1	N_{COCD}	—	Number in accordance with Kharchenko et al. (2005a, 2005b)
2	Name	—	NGC, IC or other common designation
3	RAhour	h	Cluster center in RA J2000.0
4	DEdeg	deg	Cluster center in Dec J2000.0
5	r	deg	Angular radius of the cluster
6	RV	km/s	$\overline{\mathrm{RV}}$ determined with CRVAD-2
7	e_{RV}	km/s	Mean standard error of the $\overline{\mathrm{RV}}$
8	N_{RV}	—	Number of stars for $\overline{\mathrm{RV}}$ determination
9	RV_{ref}	km/s	$\overline{\mathrm{RV}_{\mathrm{ref}}}$ from literature
10	$e_{\mathrm{RV}_{\mathrm{ref}}}$	km/s	Mean standard error of the $\overline{\mathrm{RV}_{\mathrm{ref}}}$
11	$N_{\mathrm{RV}_{\mathrm{ref}}}$	—	Number of stars for $\overline{\mathrm{RV}_{\mathrm{ref}}}$ determination
12	ref	—	$\overline{\mathrm{RV}_{\mathrm{ref}}}$ source identifier

Note: If several coordinates and angular radii were available, we selected the data from one of the sources with the following order of priority: Kharchenko et al. (2005a, 2005b), Dias et al. (2002), Mel'nik (2007).

5 Statistics of $\overline{\mathrm{RV}}$s of open clusters and stellar associations

Altogether there are 516 objects with known $\overline{\mathrm{RV}}$s in the CRVOCA. For 177 objects there are both $\overline{\mathrm{RV}}$s determined based on the CRVAD-2 as well as previously published values available. Fig. 2 shows the comparison of the best measurements taken from the literature with our newly deter-

mined $\overline{\mathrm{RV}}$s. The clusters with high-quality solutions in the literature are shown with bold symbols.

The mean difference for all 177 objects in common is $\overline{\mathrm{RV}_{\mathrm{ref}} - \overline{\mathrm{RV}}} = 0.65 \pm 0.72$ km/s. From Fig. 3 one can see that the differences increase with larger distances. This effect is not only a result of increasing errors of the RV measurements with fainter stars, but also reflects the more problematic membership selection for distant clusters. All absolute differences larger than 25 km/s are mainly caused by a very small number of cluster members (and their uncertain membership probabilities) in at least one of the determinations. Low-accurate individual RV measurements did also play a role in some cases.

We have analysed all $\overline{\mathrm{RV}}$s as a function of Galactic longitude l (Fig. 4). The curves with different amplitudes show the expected change of the RVs over l for different distances d from the Sun, if there is no intrinsic motion but just the combined effect of Solar motion and differential Galactic rotation. For the computation of these curves we used the Solar motion components and Oort constants as obtained from the sample of 650 clusters studied in Piskunov et al. (2006). As one can see, all clusters, with only few exceptions, have $\overline{\mathrm{RV}}$s typical of disk objects, i.e. their deviations from the corresponding curves are smaller than about 50 km/s.

As a result of our study, 516 of all currently known objects (28% from 1821) and 395 objects in our sample of open clusters and stellar associations with homogeneously determined parameters (61% from 650) have $\overline{\mathrm{RV}}$ estimates. Fig. 5 illustrates the current status of the determination of basic parameters of open clusters and associations (a similar illustration of the status achieved in our previous study based on the CRVAD can be found in Scholz et al. 2005). The sample of 1821 objects is very inhomogeneous with respect to the availability of basic parameters, e.g. only 57% have distance estimates, and only 55% have ages determined. One should also keep in mind that the parameters of the objects in the full sample of 1821 objects have been derived with different methods and observations so that they can not be easily compared. However, we can consider our sample of 650 objects as a homogeneous sample, for which the basic parameters (angular sizes, average proper motions and radial velocities, reddening and distances, and ages) have been obtained in a uniform way. As seen in the right part of Fig. 5, the availability of $\overline{\mathrm{RV}}$s for the clusters in this sample is biased to younger clusters: 78% of the clusters younger than $\log t = 8.3$ have $\overline{\mathrm{RV}}$ values, whereas among older clusters only 37% have $\overline{\mathrm{RV}}$s measured. Even for the nearby clusters, located within our completeness limit of 850 pc (Piskunov et al. 2006), there are $\overline{\mathrm{RV}}$ measurements available for 65% only.

6 Summary and outlook

Both catalogues, the CRVAD-2 with 54907 entries, and the CRVOCA of 516 Galactic open clusters and stellar association, can be retrieved from the Centre de Données astronomiques de Strasbourg (CDS), France via ftp or http (ftp://cdsarc.u-strasbg.fr/pub/cats/, http://vizier.u-strasbg.fr). A summary of the CRVAD-2 columns is shown in Table 2. The contents of the CRVOCA is shown in Table 3. More details describing the data in these two catalogues can be found in the corresponding ReadMe files at the CDS. These catalogues supersede the first CRVAD version (Paper I) and the previously listed RV data on open clusters in Kharchenko et al. (2005a, 2005b). Note that mean proper motions of 650 open clusters can be found in Kharchenko et al. (2005a, 2005b) and are not listed here again.

The CRVAD-2 represents our knowledge on RV measurements of relatively bright stars distributed over the whole sky in the pre-RAVE era. Only about 2% of the stars in the ASCC-2.5, which includes the complete Tycho-2 catalogue and formed the basis of the CRVAD-2, have RVs from previous measurements. The RAVE survey of the southern sky (Steinmetz 2003) aims at RV measurements for a much larger number of Tycho-2 stars. Whereas the CRVAD-2 does not extend the magnitude limit of the first CRVAD version, the RAVE observing program includes large numbers of fainter stars, too. The recently published first RAVE data release contains 25 274 RV measurements of 24 748 individual stars (Steinmetz et al. 2006). About half of these first RAVE stars are ASCC-2.5 stars, but only a negligible number of less than 50 of them have RV data in the CRVAD-2. Already with the next RAVE data release, expected in early 2007, the number of new RV stars will probably approach the number of stars in the CRVAD-2. A next version of the CRVAD will contain the first and second RAVE data releases.

We have successfully used the CRVAD-2 data in the compilation of the CRVOCA representing a big step forward in improving our knowledge on the $\overline{\mathrm{RV}}$s of Galactic open clusters and associations. The first RAVE data release includes almost no data in the Galactic plane, where most of the open clusters and associations are located. However, with the upcoming next RAVE data releases we expect to get the results of some dedicated observations of open cluster fields which we selected and proposed on the basis of our sample of 650 objects. According to our proposal, RAVE observations are currently under way or have already been finished for more than 1500 members of about 100 open clusters in 12 selected fields in the Galactic plane. We expect that these observations will allow us to compute space motions of a large number of open clusters and to study, in more detail, the kinematics and membership of some individual clusters.

Acknowledgements. This work was supported by the DFG grant 436 RUS 113/757/0-2 and by the RFBR grant 06-02-16379. We acknowledge the use of the Simbad database and the VizieR Catalogue Service operated at the CDS, the WEBDA facility at the Institute of Astronomy of the University of Vienna. Finally, we would like to thank the referee, Dr. Allende Prieto, for his comments/suggestions, which helped to improve the paper.

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